# Changes to MI

Shekhar Mishra

Proton Driver Part of LRP

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- Present capability of Main Injector
- Upgrades pre proton driver era
- Upgrades for proton driver
- Summary

# Present Status of Main Injector

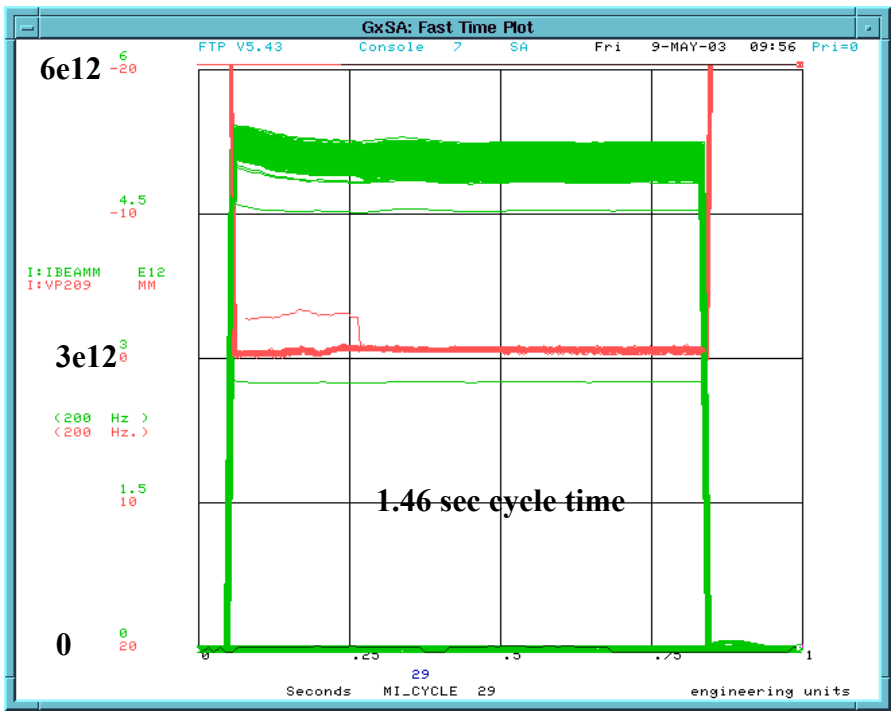
- Main Injector has been operating for more than 4 years very reliably. It has met of exceeded all its intensity design goals.
- The transverse emittances growth through the acceleration cycle is within the allowed range.
- The longitudinal emittance growth has been larger that design. I firmly believe that the new hardware we have been designing and building for about 2 years will reduce this growth.
- Main Injector acceleration efficiency is >95% and Main Injector losses are low. Only Lambertson locations in the tunnel shows any radiation.
- Main Injector has not been pushed to any limits.

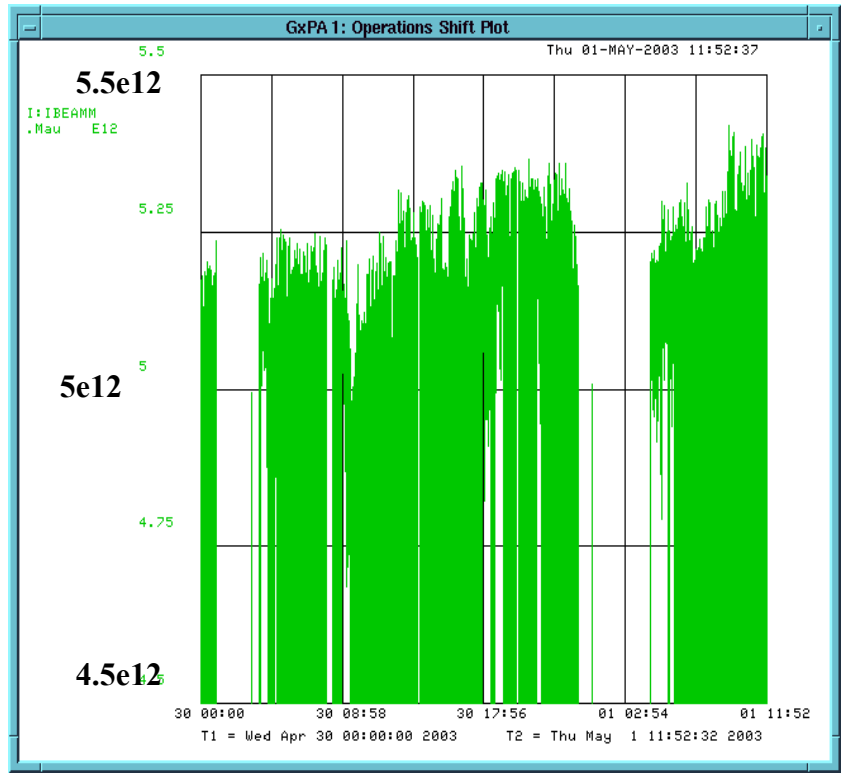
# Pbar Production Cycles

## Run II Goal: 5E12/pulse @ 1.5 sec. cycle time

**Current status**:

>5E12 @ stacking cycle time > 2 sec depending on stack size

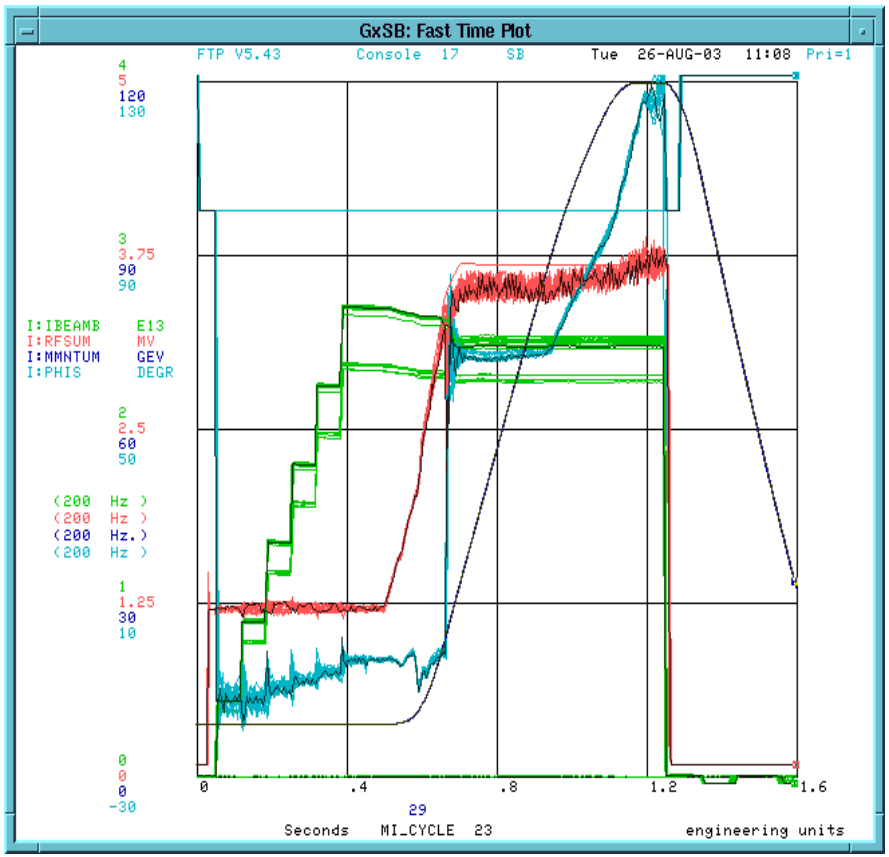


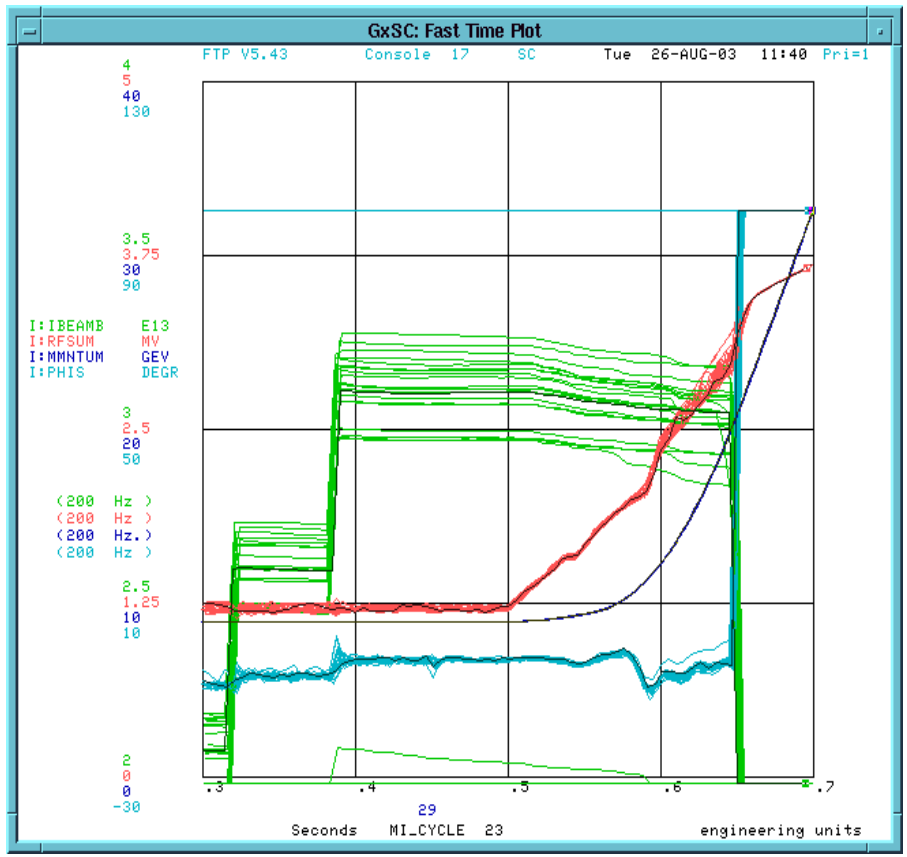




Intensity on target (E12)

# NUMI cycle

- Main Injector will deliver 3e13 ppp at 120 GeV every 1.9 Sec.




>2.5e13 ppp

>3e13 ppp, RF problem.

# Tevatron and SY120 cycles

- Main Injector has delivered in excess of 330 proton/bunch to TeV to achieve 270 proton/bunch at low beta.
- SY120 experiments needs a maximum of 5e12 ppp slow extracted over 1 sec. The slow extraction scheme has been made to work in past after the current shutdown it should be operational.
- The scheme to extract the beam to the NUMI beam line should be similar to pbar production cycle extraction. It will require some work to make it operational.

# Goal of MI Upgrades

- The physics program approved and in the planning stage requires significantly higher per pulse and integrated proton flux.
- With the present injector chain the Main Injector can be upgraded to provide higher integrated flux.
- The proposed proton driver will eject beam at a higher intensity in to the Main Injector. Main Injector will need improvements to handle higher flux.
- The extraction and targeting of a higher flux beam will require and upgrade to the extraction and targeting.

# Increased Proton Per Pulse

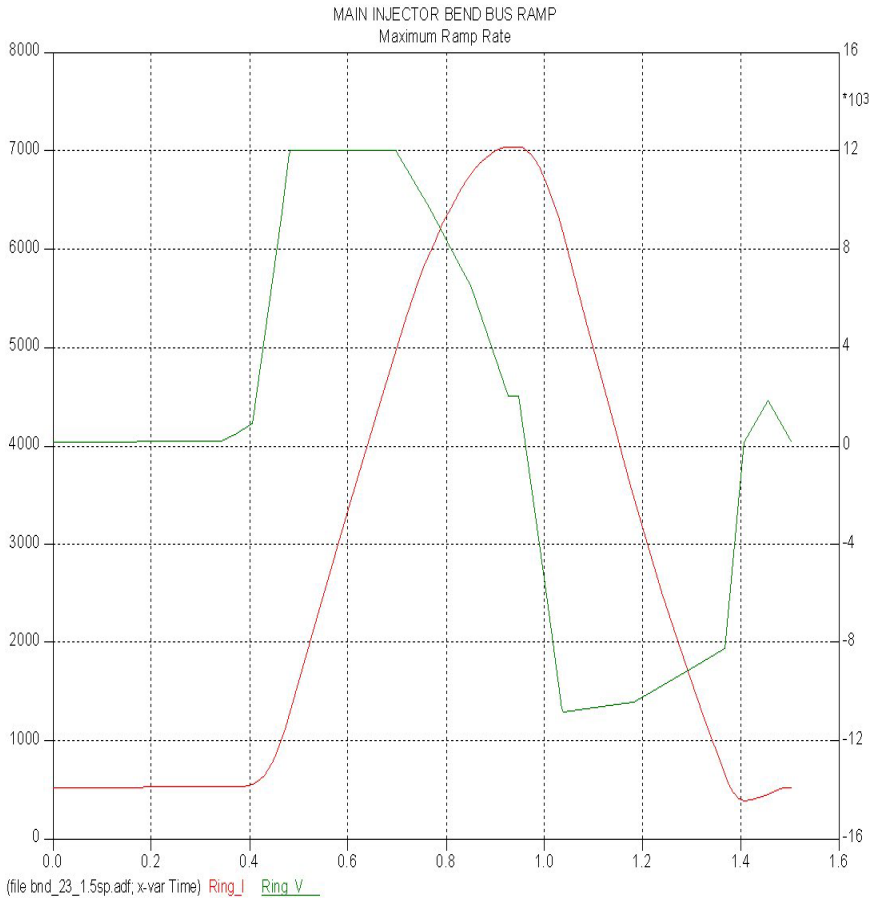
- The present injectors (Linac and Booster) is limited to about 5e12 ppp every 0.07 sec.
- One can imagine a scheme where 12 batches (rather than 6) are injected into MI from Booster and rf captured in *insignificant amount of time* to cover 6/7 of the MI.
- Could be similar to slip stacking scheme currently being developed to double the proton flux to the pbar production target.
- But the present slip stacking scheme is too slow to benefit NUMI. One needs to develop a faster stacking method as barrier stacking.
- This will provide about 50% increase in the proton per pulse to the NUMI production target.

# Increased Integrated Proton Flux

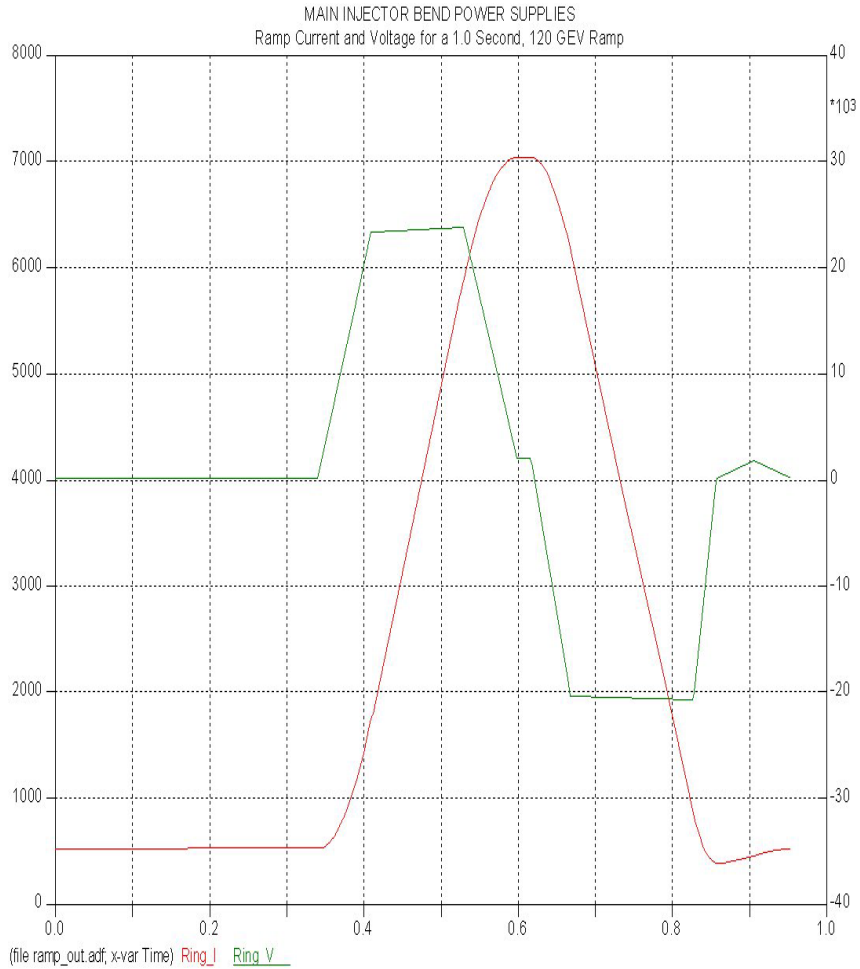
- Reduce the fill time and cycle time of the Main Injector.
  - Fill time is limited by injector and will remain the same till we build a new Linac based proton driver.
  - Main Injector cycle time can be reduced from 1.46 sec to 1 sec with a modest investment in power supply.
  - Faster ramp time will require more rf cavities. Present cavities are limited to about 270 GeV/s ramp rate.
  - Present cavity is also limited to 6e13 ppp. In the Proton Driver era one is expecting 1e14 ppp. It is desirable to upgrade and double the number of rf cavities now.
  - New RF cavities can be installed in MI30 straight section. Will need additional building for power supplies.

# MI Bend Bus Ramp

- Study done by BD EE support.




1.46 sec cycle time




0.95 sec cycle time

# MI Power Supply Requirements

- Basically, need to double the maximum available power supply voltage

Add 2 Bend power Supplies and 1 Quad power to every MI Service Building

Voltage to Ground Effects:

Bend Bus 500 v to 1kV

Quad Bus unchanged

## MI Service Buildings

- Need to be Enlarged
  - Preferably, straight out from PS room
- Transformer pads
  - Additional pads and feeder work needed
- Power Supplies
  - 2 Additional Bends and 1 additional Quad
  - Tunnel Bus Extended to pick up added PS's
  - 1 Additional Quad Tunnel Bus needed
  - Additional Water cooling for PS's
  - Additional PS controls

## Feeders:

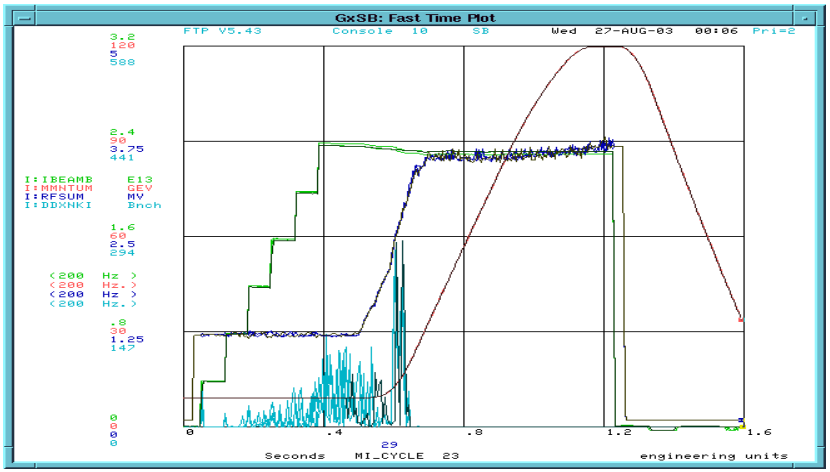
- Might Need to double the number

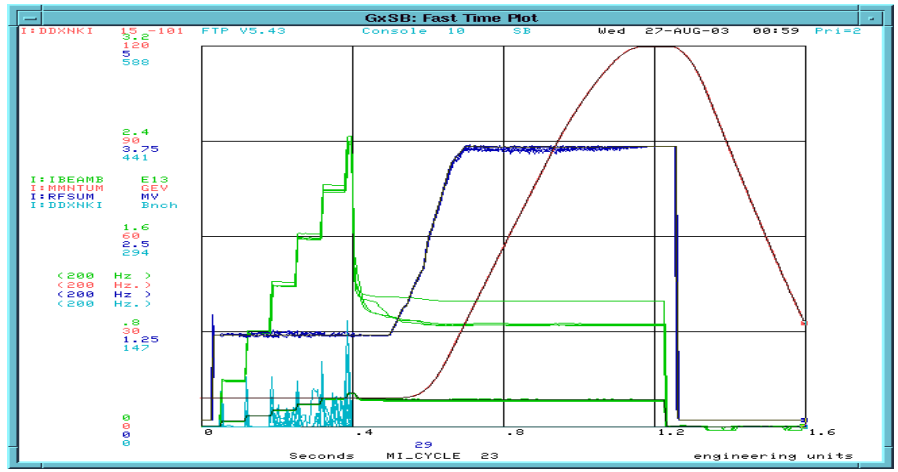
## Kautz Road Substation

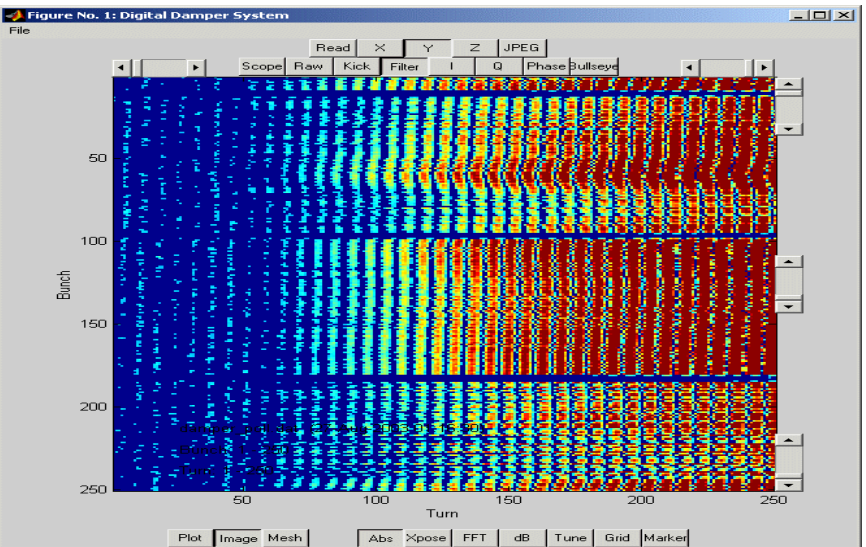
- 2 Additional 345kV transformers needed
- Substation building expanded
- 2 Additional Harmonic Filters Needed

# Higher Intensity: Instability

- Significant improvements to the MI damper system will be required to support a higher intensity (x5) operation of MI.




Present digital damper will be capable of reducing instability.

# MI Modification and Upgrades

- Gamma-t jump system: At present there is no gamma-t jump system in the MI. There is a growth of longitudinal emittance through transition in MI at the present bunch intensities.
- A new Gamma-t system will be needed for high intensity operation of MI.
- Larger aperture quadrupoles
  - At present major beam loss points in the Main Injector are at the Lambertson locations.
  - This is due to limited quadrupole aperture at the injection and extraction points.
  - A new sets of quadrupoles will be required which have larger aperture but same strength.

# MI Modification and Upgrades

- Kicker aperture are the main limiting aperture in MI.
- Main Injector has recycled Main Ring Quadrupoles. They have failed in past due to insulation problem. One should consider replacing them or at least perform R&D on their reliability at higher ramp rate.
- Radiation shielding and Collimation
  - The shielding of the MI is ok for high intensity operation. SAD may need to be modified.
  - A modest upgrade to the present MI-40 beam dump will be required. (A problem that can be solved with administrative control.)
  - A collimation system is required to minimize uncontrolled beam losses in the machine.

# MI Modification and Upgrades

- Higher order multipole correction may become more important when the beam starts filling significant fraction of the aperture.
- Super conducting Linac Injection:
  - For super-conducting Linac option a new 8 GeV H- injection system will be required. We have to develop a H- stripping at 8 GeV.
  - The beam size at 8 GeV coming from Linac will be very small. We will be required to develop a beam painting scheme to increase the size of the beam in the MI.
- Extracting and Targeting of this high intensity beam will require modification to MI.

# Summary

- Main Injector is running reliably at its design intensity and beam quality.
- Physics demands that we upgrade the Main Injector to support higher intensity operation.
- Future accelerator construction will benefit from these upgrades.
- Some of these upgrades (RF, Dampers etc) will be needed to operate the Main Injector after Proton Driver era.